



US009490932B2

(12) **United States Patent**
Umeda

(10) **Patent No.:** **US 9,490,932 B2**
(45) **Date of Patent:** **Nov. 8, 2016**

(54) **BURST SIGNAL RECEIVING APPARATUS
AND METHOD, PON OPTICAL LINE
TERMINAL, AND PON SYSTEM**

10/693 (2013.01); **H04L 7/0029** (2013.01);
H04L 7/0075 (2013.01); **H04L 7/0087**
(2013.01)

(71) Applicant: **SUMITOMO ELECTRIC
INDUSTRIES, LTD.**, Osaka-shi, Osaka
(JP)

(58) **Field of Classification Search**
CPC **H04J 14/08**; **H04L 7/0075**; **H04B 10/564**;
H04B 10/693
See application file for complete search history.

(72) Inventor: **Daisuke Umeda**, Osaka (JP)

(56) **References Cited**

(73) Assignee: **SUMITOMO ELECTRIC
INDUSTRIES, LTD.**, Osaka-shi, Osaka
(JP)

U.S. PATENT DOCUMENTS

8,155,535 B2 4/2012 Noda et al.
8,248,165 B2 8/2012 Umeda

(Continued)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 52 days.

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **14/401,871**

JP 2003-218651 A 7/2003
JP 2009-177577 A 8/2009

(22) PCT Filed: **Feb. 5, 2013**

(Continued)

(86) PCT No.: **PCT/JP2013/052580**
§ 371 (c)(1),
(2) Date: **Nov. 18, 2014**

Primary Examiner — Dzung Tran

(74) *Attorney, Agent, or Firm* — Drinker Biddle & Reath
LLP

(87) PCT Pub. No.: **WO2013/183319**
PCT Pub. Date: **Dec. 12, 2013**

(57) **ABSTRACT**

The present invention relates to a receiving apparatus **20** that receives burst signals, each including a synchronization section and a data section following the synchronization section, from a plurality of sources in a time division manner. The receiving apparatus **20** includes amplifying units **102** and **113** that amplify each burst signal; a detecting unit **116** that detects arrival of the burst signal from an output signal from the amplifying units **102** and **113**; a comparing unit **104** that compares the output signal from the amplifying units **102** and **113** with a predetermined threshold value and outputs a binary signal; and a control unit **108** that sets the timings of changing a receive function during the synchronization section by adding delay times Dai and Dbi to a detection time point where the detecting unit **116** performs an output. The control unit **108** is configured to be able to change the delay times Dai and Dbi in a plurality of ways.

(65) **Prior Publication Data**

US 2015/0163010 A1 Jun. 11, 2015

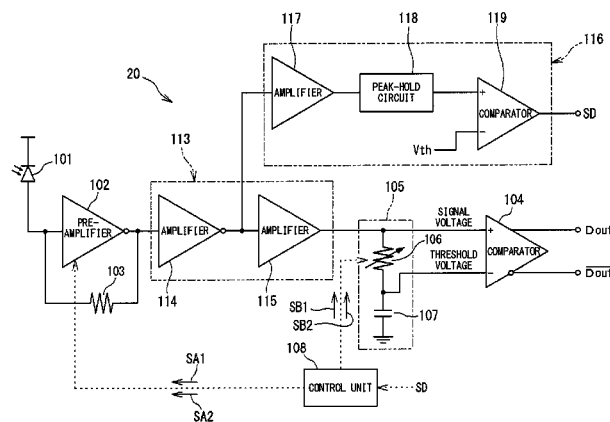
(30) **Foreign Application Priority Data**

Jun. 5, 2012 (JP) 2012-128311

(51) **Int. Cl.**
H04J 14/08 (2006.01)
H04B 10/272 (2013.01)
(Continued)

(52) **U.S. Cl.**
CPC **H04J 14/08** (2013.01); **H03G 3/3084**
(2013.01); **H04B 10/272** (2013.01); **H04B**

9 Claims, 5 Drawing Sheets



US 9,490,932 B2

Page 2

(51)	Int. Cl.		2010/0272448 A1 *	10/2010	Kubo	H03G 3/3084
	H04B 10/69	(2013.01)				398/202
	H03G 3/30	(2006.01)	2011/0170874 A1 *	7/2011	Sakuramoto	H04B 10/564
	H04L 7/00	(2006.01)				398/140
			2013/0343769 A1 *	12/2013	Noda	H04B 10/693
						398/202

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

U.S. PATENT DOCUMENTS

2008/0205906 A1 *	8/2008	Murata	H04B 10/6931	JP	2009-303159 A	12/2009
			398/208	WO	WO-2007/102189 A1	9/2007

* cited by examiner

FIG. 1

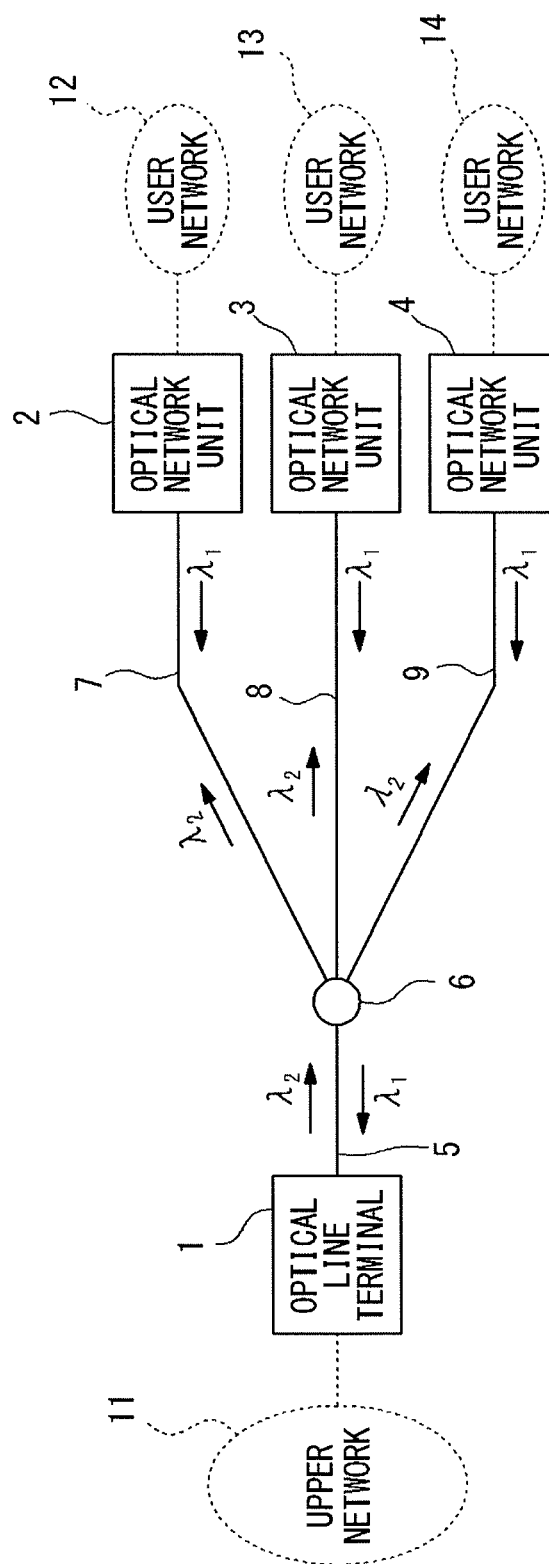


FIG. 2

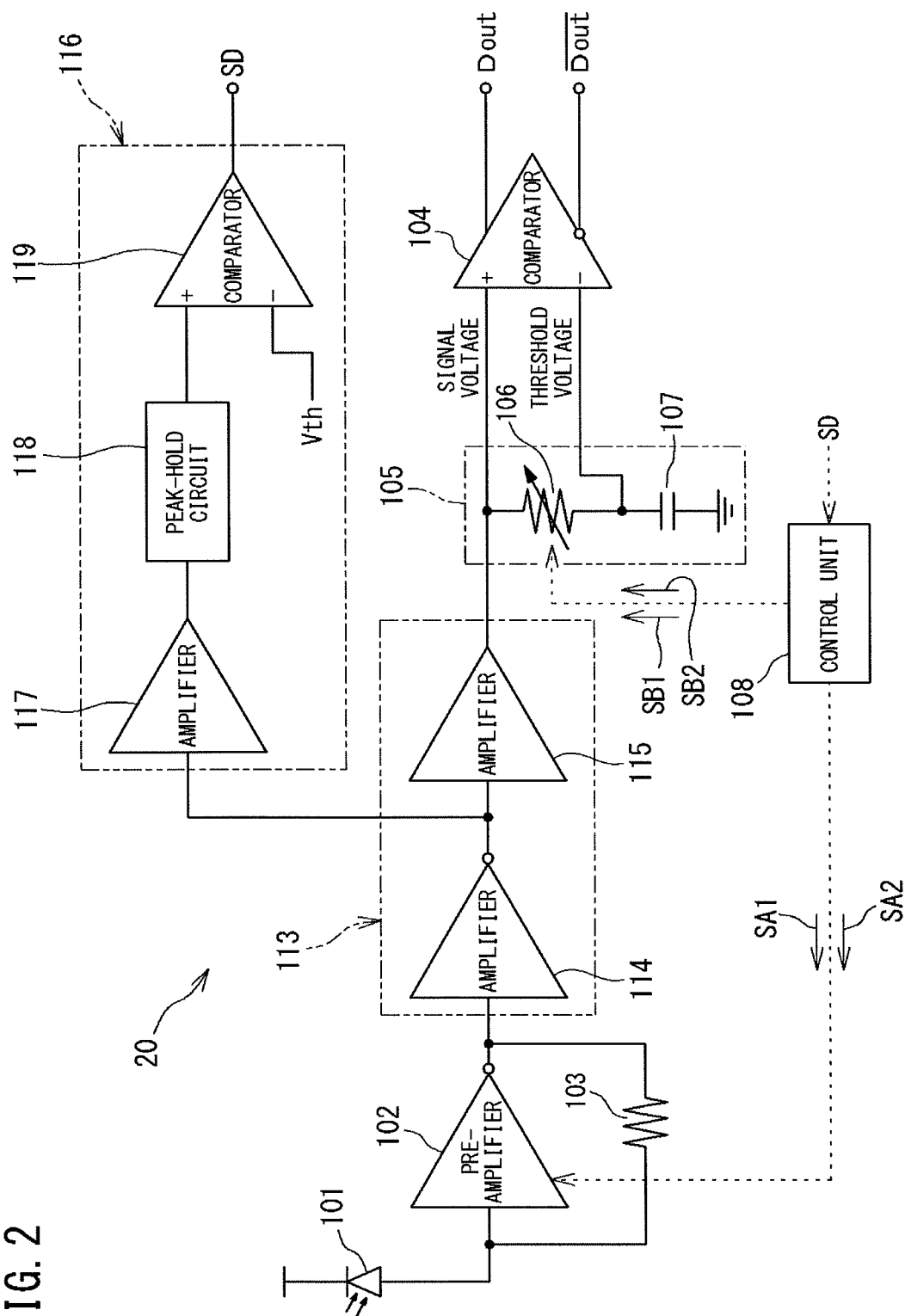


FIG. 3

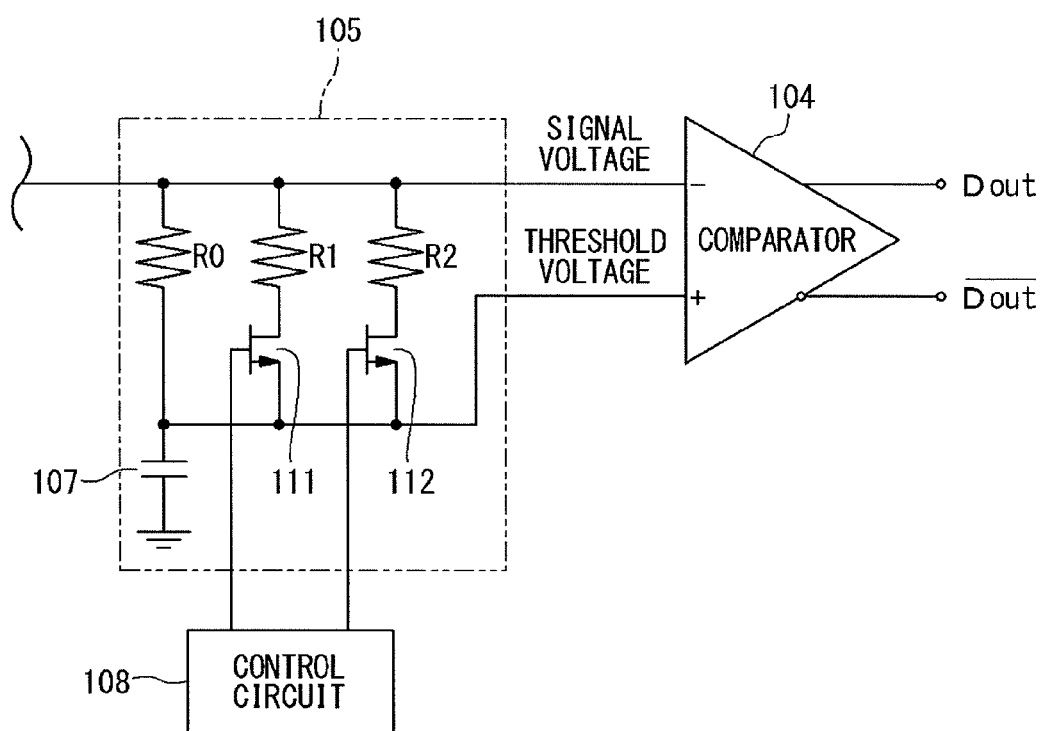


FIG. 4

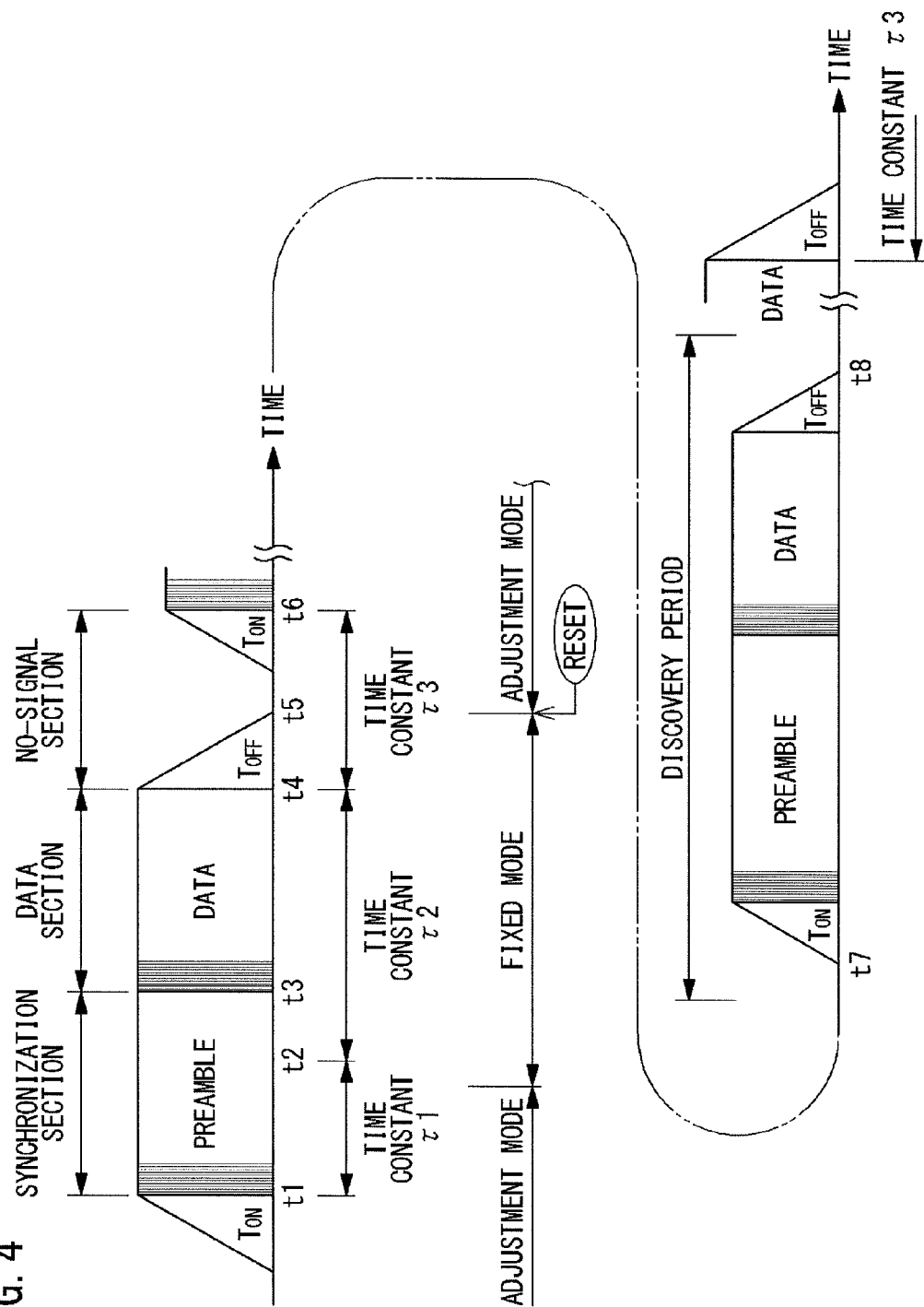
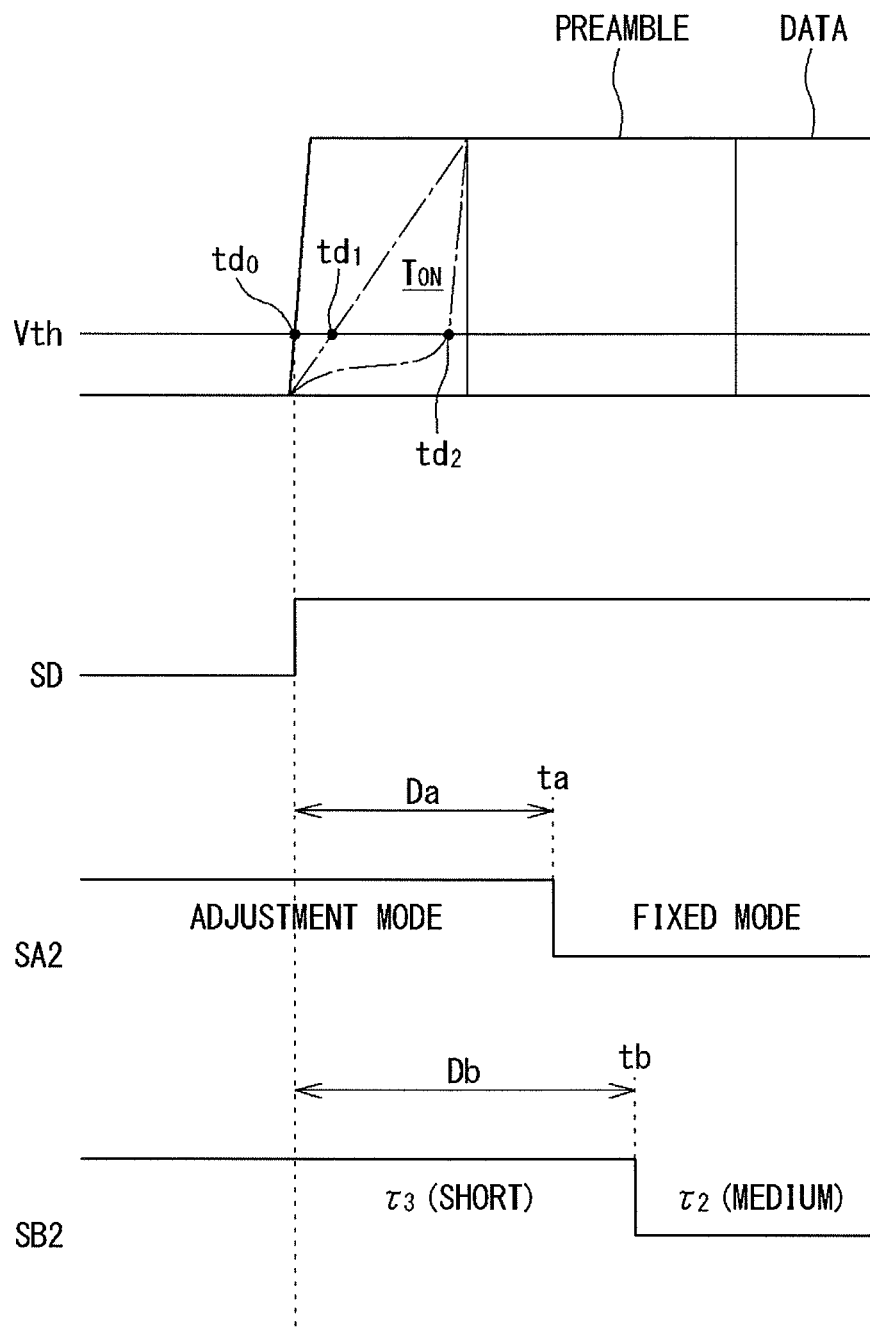


FIG. 5



1

BURST SIGNAL RECEIVING APPARATUS AND METHOD, PON OPTICAL LINE TERMINAL, AND PON SYSTEM

TECHNICAL FIELD

The present invention relates to a receiving apparatus and method for receiving, for example, burst signals which are intermittently transmitted to an optical line terminal from optical network units forming a PON (Passive Optical Network) system, and an optical line terminal and a PON system that use the receiving apparatus.

BACKGROUND ART

A PON system is a system in which an optical line terminal serving as a central station is connected to optical network units installed in a plurality of subscribers' homes by an optical fiber network where a single optical fiber is split into a plurality of optical fibers through an optical coupler.

In this case, if the plurality of optical network units simultaneously perform transmission to the optical line terminal, then transmitted data units collide with each other. Thus, the optical line terminal provides the optical network units with grants for a transmission timing and an amount of transmission data. Each optical network unit performs upstream transmission of the amount of transmission data allowed by the optical line terminal at the timing allowed by the optical line terminal.

Since the distances between the optical line terminal and the optical network units vary between the locations where the optical network units are installed, the strengths of upstream optical signals received by the optical line terminal are not uniform. Thus, upstream optical signals with various strengths intermittently arrive at the optical line terminal from the plurality of optical network units.

Hence, there is already proposed a technique in which, in order to improve the reception responsiveness to an optical burst signal, the response speed of a receiving apparatus to a burst signal is changed between a synchronization section (preamble) and a data section (payload) (see Patent Literature 1).

In this conventional art, specifically, a small time constant is set for the synchronization section to increase the followability for a burst signal, and a large time constant is set for the data section to enhance the reception tolerance to consecutive identical digits.

In addition, there is already proposed a technique in which in order that a pre-amplifier suitable for an optical receiver module of an optical line terminal can stably amplify a broadband burst signal, the operating mode of the amplifier is made switchable to either a gain adjustment mode or a gain fixed mode (see Patent Literature 2).

In this conventional art, specifically, in the adjustment mode, an appropriate gain is determined from among two levels, based on the strength of a burst signal in a synchronization section, and after the determination, the burst signal is amplified in the fixed mode where the gain is fixed.

CITATION LIST

Patent Literature

Patent Literature 1: Japanese Unexamined Patent Publication No. 2009-177577

2

Patent Literature 2: Japanese Unexamined Patent Publication No. 2009-303159

SUMMARY OF INVENTION

Technical Problem

In the case of Patent Literature 1, if the switching timing of the time constant enters the data section, then a signal is received with a small time constant set for the beginning of the data section, weakening the reception tolerance to consecutive identical digits. Thus, the time constant needs to be switched during the synchronization section.

In addition, in the case of Patent Literature 2, if the switching timing of the operating mode of the pre-amplifier enters the data section, then the beginning of the data section is not amplified by an appropriate gain. Thus, the operating mode of the preamplifier needs to be switched during the synchronization section.

Regarding this point, the optical line terminal can grasp the arrival timing of an optical burst signal in the upstream direction from a registered optical network unit, based on a grant determined thereby. Thus, the optical line terminal can set the switching timings of the time constant and the operating mode of the pre-amplifier (which may be hereinafter collectively referred to as the "receive function") in accordance with the synchronization section.

On the other hand, during a discovery period which takes place when a new optical network unit is connected, the optical line terminal cannot grasp the reception timing of an optical burst signal from the new optical network unit, and thus, needs to determine the above-described switching timings with reference to a time point where a burst is detected thereby.

However, the manner in which a signal rises during a period of time (transmission ON time) from when an optical transmitter of an optical network unit starts to transmit an optical burst signal until the optical burst signal is turned on stably varies between the models or manufacturers of optical network units. Thus, the time point where a burst is detected by the optical line terminal may vary.

In this case, the switching timings of the receive function with reference to the time point where a burst is detected also vary. Thus, there is a problem that, when the receive function is switched at inappropriate timings, the burst signal cannot be appropriately received.

In view of the above-described conventional problems, an object of the present invention is to provide a receiving apparatus, etc., capable of appropriately receiving a burst signal having a synchronization section, followed by a data section.

Solution to Problem

(1) A receiving apparatus of the present invention is a receiving apparatus that receives burst signals, each including a synchronization section and a data section following the synchronization section, from a plurality of sources in a time division manner, and includes: an amplifying unit that amplifies each of the burst signals; a detecting unit that detects arrival of the burst signal from an output signal from the amplifying unit; a comparing unit that compares the output signal from the amplifying unit with a predetermined threshold value and outputs a binary signal; and a control unit that sets a timing of changing a receive function during the synchronization section by adding a delay time to a

3

detection time point where the detecting unit performs an output, and that can change the delay time in a plurality of ways.

According to the receiving apparatus of the present invention, the control unit sets a timing of changing the receive function during the synchronization section by adding a delay time to a detection time point where the detecting unit performs an output, and can change the delay time in a plurality of ways. Thus, by adjusting the timing of changing the receive function by trial and error using a plurality of delay times, switching of the receive function can be performed at an appropriate timing.

Hence, a burst signal having a synchronization section, followed by a data section can be appropriately received.

Note that, when the receiving apparatus of the present invention can identify a time point where a burst signal from a predetermined transmitting apparatus (e.g., an optical network unit in upstream communication in a PON system) is received (e.g., when the optical network unit performs upstream transmission in accordance with a transmission time granted by an optical line terminal in the PON system), the receiving apparatus does not need to perform the above-described process in which the timing of changing the receive function is adjusted by trial and error.

Therefore, the receiving apparatus of the present invention needs to perform the above-described process in which the timing of changing the receive function is adjusted by trial and error, only when the receiving side cannot identify a time point where a burst signal from a transmitting apparatus is received (e.g., when it is a discovery period of a PON system).

Namely, in the receiving apparatus of the present invention, the control unit that sets the timing of changing the receive function during the synchronization period by adding a delay time to a detection time point where the detecting unit performs an output needs to be able to change the delay time only when a time point where a burst signal from a transmitting apparatus is received cannot be identified.

In addition, in the receiving apparatus of the present invention, in the above-described process in which the timing of changing the receive function is adjusted by trial and error, there may be a case of failing to receive a burst signal. However, once reception has succeeded, the timing of changing the receive function of the burst signal can be identified thereafter. Thus, it is not particularly problematic.

(2) In the receiving apparatus of the present invention, it is preferred that, when clock and data recovery based on the binary signal cannot be performed despite a fact that the detecting unit has detected arrival of the burst signal, the control unit change the delay time to a different value.

By doing so, compared to the case in which the value of the delay time is changed in fixed or random order, the possibility that a burst signal can be appropriately received can be increased.

(3) However, the control unit may switch a value of the delay time to a different value in fixed or random order every time the detecting unit detects arrival of a burst signal.

By doing so, there is no need to determine whether clock and data recovery based on a binary signal has succeeded. Thus, there is an advantage in ease of control to change the delay time.

(4) It is preferred that the receiving apparatus of the present invention further include a time constant circuit that can follow the output signal from the amplifying unit at different time constants.

In this case, the time constant is included in the receive function to be changed during the synchronization section.

4

As the control unit, one may be adopted that can set a timing of changing the time constant during the synchronization section by adding the delay time to a time point where the detecting unit performs an output, and that can change the delay time in a plurality of ways.

(5) In addition, in the receiving apparatus of the present invention, it is preferred that the amplifying unit include an amplifier circuit having, as a switchable operating mode, an adjustment mode where a gain is adjusted according to a strength of the burst signal, and a fixed mode where the gain is fixed.

In this case, the operating mode is included in the receive function to be changed during the synchronization section. As the control unit, one may be adopted that can set a timing of changing the operating mode during the synchronization section by adding the delay time to a time point where the detecting unit performs an output, and that can change the delay time in a plurality of ways.

(6) A receiving method of the present invention is a receiving method for a case of receiving burst signals, each including a synchronization section and a data section following the synchronization section, from a plurality of sources in a time division manner, and includes the steps of: detecting arrival of each of the burst signals from an amplified signal of the burst signal; comparing the amplified signal with a predetermined threshold value and outputting a binary signal; setting a first timing of changing a receive function during the synchronization section by adding a first delay time to a detection time point of the arrival; and setting a second timing of changing the receive function during the synchronization section by adding a second delay time to the detection time point, the second delay time being different than the first delay time.

The receiving method of the present invention includes the step of setting a timing of changing the receive function during the synchronization section by adding a first delay time to a detection time point where the detecting unit performs an output; and the step of setting a timing of changing the receive function during the synchronization section by adding a second delay time different than the first delay time to the detection time point. Thus, by performing those steps of adjusting the timing of changing the receive function by trial and error using the first and second delay times, switching of the receive function can be performed at an appropriate timing.

Hence, a burst signal having a synchronization section, followed by a data section can be appropriately received.

Note that, in the receiving method of the present invention, the first and second delay times are expressions focusing on two types of the delay time with different values. Thus, the number of values of the delay time used in the receiving method of the present invention is not limited to two.

Therefore, the receiving method of the present invention also includes a case in which the above-described two steps are repeated using the values of three types or more of the delay time and the timing of changing the receive function during the synchronization section is adjusted three times or more.

(7) An optical line terminal of the present invention is a PON optical line terminal including the receiving apparatus described in the above-described (1) to (5), and provides the same functions and effects as those provided by the receiving apparatus.

(8) In the optical line terminal of the present invention, it is preferred that the control unit re-set the timing for a discovery period for registering the optical network units.

The reason for that is that since, as described above, the optical line terminal cannot pre-detect the transmission timing of a burst signal from a new optical network unit during a discovery period, the optical line terminal needs to determine the timing of changing the receive function during a synchronization section, from a time point where a burst signal is detected thereby. Thus, the utility value for when the present invention is adopted is high.

(9) A PON system of the present invention is a PON system including, as a component, an optical line terminal having the receiving apparatus described in the above-described (1) to (5), and provides the same functions and effects as those provided by the receiving apparatus.

Advantageous Effects of Invention

As described above, according to the present invention, a burst signal including a synchronization section and a data section can be appropriately received.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is an overall configuration diagram of a PON system according to an embodiment of the present invention.

FIG. 2 is a circuit diagram of a receiver circuit provided in an optical line terminal.

FIG. 3 is a circuit diagram showing the details of a time constant circuit.

FIG. 4 is an illustrative diagram showing an example of burst signal arrival order.

FIG. 5 is a time chart showing a temporal relationship between the first half portion of a burst signal, a burst detection signal, and the switching timings of a pre-amplifier and the time constant circuit.

DESCRIPTION OF EMBODIMENTS

An embodiment of the present invention will be described below based on the drawings.

[Overall Configuration of a PON System]

FIG. 1 is an overall configuration diagram of a PON system according to an embodiment of the present invention.

In FIG. 1, an optical line terminal (OLT) 1 is installed as a central station for a plurality of optical network units (ONUs) 2 to 4. The optical network units 2 to 4 are installed in PON system subscribers' homes, respectively.

A single optical fiber 5 connected to the optical line terminal 1 is split into a plurality of optical fibers (branch lines) 7 to 9 through an optical coupler 6 which is a passive optical splitting node. The optical network units 2 to 4 are connected to the ends of the split optical fibers 7 to 9, respectively.

The optical line terminal 1 is communicably connected to an upper network 11, and the optical network units 2 to 4 are communicably connected to their respective user networks 12 to 14.

Although FIG. 1 shows three optical network units 2 to 4, it is possible to connect, for example, 32 optical network units by splitting an optical fiber into 32 optical fibers through the single optical coupler 6. In addition, although in FIG. 1 only one optical coupler 6 is used, by providing a plurality of optical couplers 6 longitudinally, more optical network units can be connected to the optical line terminal 1.

Note that the distances from the optical line terminal 1 to the optical network units 2 to 4 are not uniform, and thus, the strengths of signals coming from the optical network units 2 to 4 are not uniform, either.

In FIG. 1, in the upstream direction from the optical network units 2 to 4 to the optical line terminal 1, data is transmitted at wavelength λ_1 .

On the other hand, in the downstream direction from the optical line terminal 1 to the optical network units 2 to 4, data is transmitted at wavelength λ_2 . The wavelengths λ_1 and λ_2 are set based on, for example, Clause 60 of IEEE Standard 802.3ah-2004 in the case of GE-PON.

In the above-described PON system, downstream transmission from the optical line terminal 1 to the optical network units 2 to 4 is performed at any time in broadcast form. Each of the optical network units 2 to 4 captures only those downstream frames destined therefor, and discards other downstream frames.

On the other hand, upstream transmission from the optical network units 2 to 4 to the optical line terminal 1 is performed under the control of the optical line terminal 1. Each of the optical network units 2 to 4 performs upstream transmission of an amount of transmission data allowed for transmission at a transmission time allowed (granted) for transmission by the optical line terminal 1.

[Burst Receiver Circuit of the Optical Line Terminal]

FIG. 2 is a circuit diagram of a receiver circuit (receiving apparatus) 20 provided in the optical line terminal 1.

As shown in FIG. 2, the receiver circuit 20 of the present embodiment includes a photodiode 101, a pre-amplifier 102, a feedback resistor 103, a post-amplifier 113, a time constant circuit 105, a comparator 104, and a signal detector circuit 116.

Of the components, the photodiode 101 which is a light receiving element receives an optical burst signal generated based on a binary signal (digital signal), and converts the optical burst signal into an electrical signal and outputs the electrical signal.

The output signal from the photodiode 101 is amplified by the pre-amplifier 102 having the feedback resistor 103 connected between its input and output. The amplified signal (the burst signal formed of the electrical signal) outputted from the pre-amplifier 102 is inputted to the post-amplifier 113 subsequent to the pre-amplifier 102.

The post-amplifier 113 includes two amplifiers 114 and 115. The amplifiers 114 and 115 further amplify the amplitude of the burst signal outputted from the pre-amplifier 102. The pre-amplifier 102 and the post-amplifier 113 compose an amplifying unit that amplifies the burst signal formed of the electrical signal outputted from the photodiode 101.

An output signal from the post-amplifier 113 is inputted as a signal voltage to one of the input terminals of the comparator 104. In addition, a voltage which is the burst signal outputted through the time constant circuit 105 is inputted as a threshold voltage to the other input terminal of the comparator 104.

The time constant circuit 105 is formed of a low-pass filter including a variable resistor 106 whose resistance value is variable by external control; and a capacitor 107 whose one end is connected to the resistor 106 and whose other end is the ground potential. In this case, when the resistance value of the variable resistor 106 is R and the capacitance of the capacitor 107 is C, the time constant τ can be calculated by $\tau=R \cdot C$.

The comparator 104 compares the signal voltage with the threshold voltage and outputs the comparison result as a binary signal (digital signal) Dout of 0 or 1 and a logically

inverted signal thereof. The resistance value of the resistor **106** can be changed by a control unit **108**.

The signal detector circuit **116** composes a detecting unit that detects arrival of the burst signal from an output signal from the post-amplifier **113**. The signal detector circuit **116** includes an amplifier **117**, a peak-hold circuit **118**, and a comparator **119**.

The input terminal of the amplifier **117** is connected between the amplifiers **114** and **115** in the post-amplifier **113**. An output signal from the amplifier **114** is inputted to the peak-hold circuit **118**. The peak-hold circuit **118** holds a maximum voltage value of the amplifier **117** and outputs the maximum voltage value to the comparator **119** subsequent thereto.

The comparator **119** compares the held voltage value with a predetermined threshold value (reference voltage) V_{th} . When the voltage value is greater than or equal to the threshold value V_{th} , the comparator **119** sets a burst detection signal SD to "High". When the voltage value is less than the threshold value V_{th} , the comparator **119** sets the burst detection signal SD to "Low".

The pre-amplifier **102** can operate in either an "adjustment mode" which is an operating mode where the gain is adjusted according to the strength of the burst signal (electrical output) inputted thereto from the photodiode **101** or a "fixed mode" which is an operating mode where the gain is fixed.

As such a pre-amplifier **102** capable of switching the operating mode, there is, for example, one shown in the above-described Patent Literature 2. In the present embodiment, the same pre-amplifier as that one is adopted. Note that the operating mode of the pre-amplifier **102** may have a third mode other than those described above.

For the already registered optical network units **2** to **4**, the control unit **108** performs predetermined dynamic bandwidth allocation in response to a request, and generates grants each including the transmission timing and amount of transmission data of an optical burst signal to be transmitted by each of the optical network units **2** to **4**, and performs downstream transmission of the grants to the optical network units **2** to **4**.

The control unit **108** grasps the arrival times and time lengths of synchronization sections and data sections of the optical burst signals to be transmitted by the optical network units **2** to **4**, based on the transmission timings granted thereby to the optical network units **2** to **4**.

The control unit **108** performs downstream transmission of a discovery gate during a "discovery period" (see FIG. 4) for registering an unregistered optical network unit (not shown). The control unit **108** provides an LLID to an optical network unit having performed upstream transmission of a registration request in response to the discovery gate, and thereby newly registers the optical network unit.

In addition, the control unit **108** controls the switching timing of the operating mode of the pre-amplifier **102** by control signals SA1 and SA2, and controls the switching timing of the time constant of the time constant circuit **105** by control signals SB1 and SB2 (see FIG. 2).

Of the control signals SA1, SA2, SB1, and SB2, the control signals SA1 and SB1 are control signals for the registered optical network units **2** to **4**, and the control signals SA2 and SB2 are control signals for unregistered optical network units.

Namely, the control unit **108** controls the switching of the pre-amplifier **102** and the time constant circuit **105** by the control signals SA1 and SB1 during a normal period other than the discovery period, and controls the switching of the

pre-amplifier **102** and the time constant circuit **105** by the control signals SA2 and SB2 during the discovery period.

[Switching Control of the Receive Function During the Normal Period]

FIG. 3 is a circuit diagram showing a specific example of the time constant circuit **105** for making the resistance value of the resistor **106** variable. FIG. 4 is an illustrative diagram showing an example of burst signal arrival order.

As shown in FIG. 3, the time constant circuit **105** includes a series unit of a resistor R0 (resistance value R0) and the capacitor **107** which is provided between a signal potential and the ground potential.

In addition, the time constant circuit **105** includes a series unit of a resistor R1 (resistance value R1) connected in parallel to the resistor R0 and a switching element (e.g., a MOS-FET) **111**; and likewise a series unit of a resistor R2 (resistance value R2) connected in parallel to the resistor R0 and a switching element **112**.

Here, in EPON (IEEE 802.3ah) and 10G-EPON (IEEE 802.3av), a burst signal is composed of the following portions 1) to 4) in this order from the beginning (see FIG. 4).

1) Transmission ON section (T_{ON}): a time period for a transmitter of an ONU to stably turn on a burst signal. Note, however, that a signal waveform is not guaranteed during this section.

2) Synchronization section: a time period for a receiver of the OLT to synchronize to the burst signal. It is also called a preamble section.

3) Data section: a time period during which data is transmitted. It is also called a payload section.

4) Transmission OFF section (T_{OFF}): a time period for the transmitter of the ONU to turn off the burst signal.

With reference to FIG. 4, during the normal period, the control unit **108** grasps in advance time t1 at which the preamble portion starts to be received first; time t3 at which the data portion starts to be received first; time t4 at which the reception of the burst signal is completed; and time t5 at which the burst signal is turned off. In addition, the control unit **108** also grasps in advance time t6 at which the next burst signal starts to arrive after a no-signal section.

Hence, during the normal period, the control unit **108** switches the time constant of the time constant circuit **105** by turning on/off the control terminals of the switching elements **111** and **112** (e.g., the gates of MOS-FETs) in the time constant circuit **105** by the control signal SA1 as shown in the following table 1.

TABLE 1

Control example 1 ($R2 < R1$)		Switching element 111	Switching element 112	Time constant
First part of the signal	Preamble section (first half)	On	Off	$\tau 1$ (medium)
Last part of the signal	Preamble section (second half) and data section	Off	Off	$\tau 2$ (long)
No-signal section		Off	On	$\tau 3$ (short)

In table 1, it is assumed that the resistance values R1 and R2 have a relationship of $R2 < R1$. Different controls are performed on/on/off of the switching elements **111** and **112** for the first part and last part of the burst signal and the no-signal section of the burst signal.

First, during a part of the synchronization section which is the first part of the signal (time t1 to t2), the switching

element **111** is placed in an on state, and the switching element **112** is placed in an off state.

By this, when the on-resistance of the switching element **111** is R_{s1} , the time constant circuit **105** is formed such that the capacitor **107** (capacitance C) is connected to parallel resistors of the resistor R_0 and the resistors (R_1+R_{s1}) . In this case, the time constant τ_1 is as shown in the following equation (1):

$$\tau_1 = \{R_0 \cdot (R_1 + R_{s1}) / (R_0 + R_1 + R_{s1})\} \cdot C \quad (1)$$

Note that time t_2 can be set to a predetermined time a bit before time t_3 which is the end of the preamble.

Subsequently, during the other part of the synchronization section (time t_2 to t_3) and the data section (time t_3 to t_4) which are the last part of the signal, i.e., time t_2 to t_4 , the switching elements **111** and **112** are both placed in an off state. By this, the resistors R_1 and R_2 in the time constant circuit **105** become invalid, resulting in a time constant of only the resistor R_0 and the capacitor **107** (capacitance C). This time constant τ_2 is as shown in the following equation (2):

$$\tau_2 = R_0 \cdot C \quad (2)$$

Subsequently, during the no-signal section (time t_4 to t_6), the switching element **111** is placed in an off state and the switching element **112** is placed in an on state. By this, when the on-resistance of the switching element **112** is R_{s2} , the time constant is of the resistor R_0 , parallel resistors of R_2+R_{s2} , and the capacitor **107** (capacitance C). This time constant τ_3 is as shown in the following equation (3):

$$\tau_3 = \{R_0 \cdot (R_2 + R_{s2}) / (R_0 + R_2 + R_{s2})\} \cdot C \quad (3)$$

In the above-described equations (1) to (3), when another resistor (R_1 or R_2) is connected in parallel to the resistor R_0 , the resistance value of the entire parallel resistors is smaller than the resistor R_0 . In addition, the smaller the resistance value connected in parallel, the smaller the resistance value of the entire parallel resistors. Therefore, the following inequality (4) holds:

$$\tau_3 < \tau_1 < \tau_2 \quad (4)$$

When this is represented as a relative relationship between the lengths of the time constant, the first part of the signal is "medium", the last part of the signal is "long", and the no-signal section is "short".

The control unit **108** switches the time constant of the time constant circuit **105** in the above-described manner, and sets the time constant for the first half of the synchronization section (t_1 to t_2) to be relatively short. By this, the threshold voltage which is the output voltage from the time constant circuit **105** promptly follows the median of the preamble.

In particular, when a bit-inversion repeating signal such as 0, 1, 0, 1, . . . is used in the preamble, since the frequency component of the signal is high (there is only one bit of a consecutive identical symbol), by setting a short time constant, the median can be rapidly detected. By this, the responsiveness to the burst signal is improved.

During a period from the second half of the synchronization section to the data section which is the last part of the signal (t_2 to t_4), the control unit **108** sets the time constant to be longer than that for the first part of the signal, according to the encoding format in the data section. By this, the threshold voltage in the data section is stabilized so as not to shift much from the center of the amplitude.

Furthermore, the control unit **108** sets the time constant to be shortest in the no-signal section to promptly bring the threshold voltage back to a no-signal level. Therefore, even

immediately after receiving a burst signal with high optical signal strength (amplitude), the threshold voltage can be promptly brought back to a no-signal level and thus a no-signal period can be reduced. Hence, the upstream communication bandwidth can be more effectively utilized.

During the normal period, the control unit **108** switches the operating mode of the pre-amplifier **102** by the control signal SB_1 at the timings shown in FIG. 4.

Specifically, until the time point a bit before time t_2 , the control unit **108** sets the operating mode of the pre-amplifier **102** to an "adjustment mode" to allow the pre-amplifier **102** to adjust the gain according to the strength of the burst signal.

During a period after the above-described time point where the signal strength is stabilized, the control unit **108** sets the operating mode of the pre-amplifier **102** to a "fixed mode" to fix the gain of the pre-amplifier **102** at a predetermined value.

Note that at time t_5 at which the burst signal is turned off, the control unit **108** changes the fixed mode back to an "adjustment mode", and resets the value of the output voltage held by the pre-amplifier **102** to bring the gain back to its initial value. By this, it becomes easier to adjust the gain for the next burst signal.

[Switching Control of the Receive Function During the Discovery Period]

FIG. 5 is a time chart showing a temporal relationship between the first half portion of a burst signal, a burst detection signal SD , and control signals SA_2 and SB_2 for the pre-amplifier **102** and the time constant circuit **105**.

As described above, the optical line terminal **1** waits for upstream transmission from an unregistered optical network unit during the discovery period (see FIG. 4). For an optical burst signal received during the discovery period (an optical burst signal at time t_7 to t_8 in FIG. 4), the optical line terminal **1** cannot perform switching control of the pre-amplifier **102** and the time constant circuit **105** using time t_1 to t_6 grasped in advance thereby.

Hence, as shown in FIG. 5, the control unit **108** determines the switching timings of the operating mode and the time constant with reference to the burst detection signal SD outputted from the signal detector circuit **116**, and uses the determined timings as a trigger to change the states of the control signals SA_2 and SB_2 .

Specifically, the control unit **108** pre-stores delay times Da and Db from a burst detection time point td_0 . The control unit **108** uses time to be obtained by adding the delay time Da to the burst detection time point td_0 as the switching timing of the operating mode, and uses time t_b obtained by adding the delay time Db to the burst detection time point td_0 as the switching timing of the time constant.

Namely, the control signal SA_2 which is outputted to the pre-amplifier **102** from the control unit **108** during the discovery period is a control signal that sets the operating mode to an adjustment mode until time t_a which is obtained by adding the delay time Da to an SD rise time point td_0 , and sets the operating mode of the pre-amplifier **102** to a fixed mode after that time t_a .

In addition, the control signal SB_2 which is outputted to the time constant circuit **105** from the control unit **108** during the discovery period is a control signal that sets the time constant of the time constant circuit **105** to shortish " τ_3 " until time t_b which is obtained by adding the delay time Db to the SD rise time point td_0 , and sets the time constant of the time constant circuit **105** to longer " τ_2 " after that time t_b .

11

Note that, as shown in FIG. 5, the delay times D_a and D_b are set such that both of time t_a and t_b are within the synchronization section and $t_a < t_b$. By this, after the amplitude of an output signal from the pre-amplifier 102 is stabilized, the time constant can be switched.

Meanwhile, if, as indicated by a solid line at the top of FIG. 5, the manner in which the beginning of the burst signal rises (the form of a transmission ON section) is sufficiently fast and has a form close to an ideal rectangular wave, then even if the source of the burst signal is changed or even if the reception strength of the burst signal is changed, the burst detection time point td_0 does not move forward or backward.

However, the manner in which the beginning of the burst signal rises varies between the models or manufacturers of optical network units. For example, as indicated by imaginary lines at the top of FIG. 5, the burst signal may exceed the threshold value V_{th} at time td_1 which is substantially the center of the transmission ON section, or may exceed the threshold value V_{th} at time td_2 immediately before the start of the synchronization section. In addition, as indicated by the solid line, the burst signal may exceed the threshold value V_{th} at time td_0 which is the front edge of the transmission ON section.

Therefore, in practice, the rise of the burst detection signal SD often varies forward or backward in the range of time td_0 to td_2 . In this case, time t_a and t_b calculated based on the SD also vary forward or backward.

In particular, when the rise of the burst detection signal SD is delayed later than time td_2 , time t_a and t_b are also correspondingly delayed significantly. At worst, both of time t_a and t_b enter the data section and accordingly the burst signal may not be able to be appropriately received.

In view of this, in the present embodiment, a plurality of switching timings are prepared in advance, and the switching timings are changed in fixed order or randomly every discovery period for registering an optical network unit. By this, the above-described problem is solved.

Specifically, the control unit 108 holds delay times D_{ai} and D_{bi} of at least two types, long and short ($i=1, 2, \dots$).

The control unit 108 changes each of the held delay times D_{ai} and D_{bi} to a different value every discovery period, and thereby sets each of the switching timings of the control signals SA2 and SB2 to a different time point for each discovery period.

For example, when the switching timings of the control signals SA2 and SB2 are changed in fixed order, the control unit 108 uses delay times D_{a1} and D_{b1} during a predetermined discovery period, and uses delay times D_{a2} and D_{b2} during the next discovery period.

When the switching timings of the control signals SA2 and SB2 are changed randomly, the control unit 108 randomly selects arbitrary delay times D_{ai} and D_{bi} from among the held delay times during an arbitrary discovery period, and randomly selects other delay times D_{aj} and D_{bj} ($j \neq i$) during the next discovery period.

[Effect of the Burst Receiver Circuit]

As described above, according to the burst receiver circuit 20 of the present embodiment, when the control unit 108 sets the switching timings of the receive function (specifically, the operating mode of the pre-amplifier 102 and the time constant of the time constant circuit 105) for the synchronization section by adding delay times D_{ai} and D_{bi} to a time point td_0 to td_2 at which a burst signal is detected by the signal detector circuit 116, the control unit 108 changes the timings of the switching timings by adopting different sets of delay times D_{ai} and D_{bi} in fixed order or randomly.

12

Hence, even if the burst signal arrival time point td_0 to td_2 moves forward or backward, by adding a different set of delay times D_{ai} and D_{bi} , the switching timings of the control signals SA2 and SB2 can be set at appropriate time points within the synchronization section.

Accordingly, by making a change to the receive function using a plurality of sets of delay times D_{ai} and D_{bi} a plurality of times, the receive function can be changed at appropriate timings. Thus, the optical line terminal 1 can appropriately receive even a burst signal that is transmitted during a discovery period from an optical network unit that cannot set a long synchronization section.

[First Variant]

Although in the above-described embodiment the delay times D_{ai} and D_{bi} are changed in fixed or random order, a determination as to whether to change the delay times D_{ai} and D_{bi} may be made according to whether a burst signal has been able to be appropriately received.

Specifically, a clock and data recovery circuit (CDR circuit) is normally provided subsequent to the burst receiver circuit 20.

Hence, a signal indicating as to whether clock and data recovery has succeeded is inputted to the control unit 108.

Then, when the control unit 108 obtains a recovery success signal from the clock and data recovery circuit within a predetermined period of time after a burst detection signal SD of the signal detector circuit 116 rises, the control unit 108 does not change the delay times D_{ai} and D_{bi} .

On the other hand, when the control unit 108 does not obtain the above-described recovery success signal within the predetermined period of time after the burst detection signal SD of the signal detector circuit 116 rises, the control unit 108 changes the delay times D_{ai} and D_{bi} .

By doing so, compared to the case in which the values of the delay times D_{ai} and D_{bi} are changed in fixed or random order, the possibility that reception of a burst signal can be appropriately received can be increased.

However, when, as in the above-described embodiment, the values of the delay times D_{ai} and D_{bi} are changed in fixed or random order, there is no need to determine from a signal from the clock and data recovery circuit whether the recovery has succeeded. Thus, there is an advantage in ease of control to change the delay times D_{ai} and D_{bi} .

[Other Variants]

The embodiment (including the above-described variant) disclosed herein is in all respects as illustrative and not restrictive. The scope of right of the present invention includes all changes which come within the range of equivalency of the configurations recited in the claims, but not the above-described embodiment.

For example, although in the above-described embodiment the control unit 108 controls the switching timings of both of the operating mode of the pre-amplifier 102 and the time constant of the time constant circuit 105, the configuration may be such that the control unit 108 controls only one of them.

In addition, in the above-described embodiment, the receive function whose switching timings are to be controlled by the control unit 108 are not limited to the operating mode of the pre-amplifier 102 and the time constant of the time constant circuit 105.

REFERENCE SIGNS LIST

- 1 OPTICAL LINE TERMINAL
- 2 to 4 OPTICAL NETWORK UNIT

13

20: BURST RECEIVER CIRCUIT (RECEIVING APPARATUS)

102: PRE-AMPLIFIER (AMPLIFYING UNIT)

104: COMPARATOR

105: TIME CONSTANT CIRCUIT

108: CONTROL UNIT

113: POST-AMPLIFIER (AMPLIFYING UNIT)

114: AMPLIFIER

115: AMPLIFIER

116: SIGNAL DETECTOR CIRCUIT (DETECTING UNIT) 10

The invention claimed is:

1. A burst signal receiving apparatus that receives burst signals, each including a synchronization section and a data section following the synchronization section, from a plurality of sources in a time division manner, the apparatus comprising:

an amplifying unit that amplifies each of the burst signals;

a detecting unit that detects arrival of the burst signal from an output signal from the amplifying unit;

a comparing unit that compares the output signal from the amplifying unit with a predetermined threshold value and outputs a binary signal; and

a control unit that sets a timing of changing a receive function during the synchronization section by adding a delay time to a detection time point where the detecting unit performs an output, and that holds the delay times of at least two types that are a long type and a short type.

2. The burst signal receiving apparatus according to claim 1, wherein, when clock and data recovery based on the binary signal cannot be performed despite a fact that the detecting unit has detected arrival of the burst signal, the control unit changes the delay time to a different value.

3. The burst signal receiving apparatus according to claim 1, wherein the control unit changes a value of the delay time in fixed or random order every time the detecting unit detects arrival of a burst signal.

4. The burst signal receiving apparatus according to claim 1, further comprising a time constant circuit that can follow the output signal from the amplifying unit at different time constants, wherein

the time constant is included in the receive function to be changed during the synchronization section.

5. The burst signal receiving apparatus according to claim 1, wherein

the amplifying unit includes an amplifier circuit having, as a switchable operating mode, an adjustment mode where a gain is adjusted according to a strength of the burst signal, and a fixed mode where the gain is fixed, and

14

the operating mode is included in the receive function to be changed during the synchronization section.

6. A burst signal receiving method for a case of receiving burst signals, each including a synchronization section and a data section following the synchronization section, from a plurality of sources in a time division manner, the method comprising the steps of:

detecting arrival of each of the burst signals from an amplified signal of the burst signal;

comparing the amplified signal with a predetermined threshold value and outputting a binary signal;

setting a first timing of changing a receive function during the synchronization section by adding a first delay time to a detection time point of the arrival; and

setting a second timing of changing the receive function during the synchronization section by adding a second delay time to the detection time point, the second delay time being different than the first delay time.

7. A PON optical line terminal that forms a PON system with a plurality of optical network units and performs multiple access control of upstream optical signals transmitted from the optical network units in a time division manner, the optical line terminal comprising:

a light receiving element that receives an upstream optical signal transmitted from each of the optical network units and performs photoelectric conversion on the upstream optical signal;

an amplifying unit that amplifies a burst signal formed of an electrical signal outputted from the light receiving element;

a detecting unit that detects arrival of the burst signal from an output signal from the amplifying unit;

a comparing unit that compares the output signal from the amplifying unit with a predetermined threshold value and outputs a binary signal; and

a control unit that sets a timing of changing a receive function during the synchronization section by adding a delay time to a detection time point where the detecting unit performs an output, and that holds the delay times of at least two types that are a long type and a short type.

8. The PON optical line terminal according to claim 7, wherein the control unit re-sets the timing for a discovery period for registering the optical network units.

9. A PON system comprising:

a plurality of optical network units; and

the optical line terminal according to claim 7.

* * * * *